

WILEY

Sound as a Deterrent to Rats and Mice

Author(s): C. Merle Sprock, Walter E. Howard and Fred C. Jacob

Source: *The Journal of Wildlife Management*, Vol. 31, No. 4 (Oct., 1967), pp. 729-741

Published by: Wiley on behalf of the Wildlife Society

Stable URL: <http://www.jstor.org/stable/3797976>

Accessed: 10-01-2018 16:48 UTC

JSTOR is a not-for-profit service that helps scholars, researchers, and students discover, use, and build upon a wide range of content in a trusted digital archive. We use information technology and tools to increase productivity and facilitate new forms of scholarship. For more information about JSTOR, please contact support@jstor.org.

Your use of the JSTOR archive indicates your acceptance of the Terms & Conditions of Use, available at <http://about.jstor.org/terms>



Wildlife Society, Wiley are collaborating with JSTOR to digitize, preserve and extend access to *The Journal of Wildlife Management*

JSTOR

EXHIBIT C-2

SOUND AS A DETERRENT TO RATS AND MICE¹

C. MERLE SPROCK, Department of Agricultural Engineering, University of California, Davis
WALTER E. HOWARD, Department of Animal Physiology, University of California, Davis
FRED C. JACOB, Department of Agricultural Engineering, University of California, Davis²

Abstract: Under laboratory conditions, a continuous sound at less than 120 db (decibels) at any given frequency from 4-19 kc (kilocycles per second) was ineffective in deterring wild and laboratory rats (*Rattus norvegicus*) from entering and foraging in interconnected boxes (6 × 6 × 5 ft). When the sound output was intermittent and the frequency varied an entire octave (6-12 kc), and was out of phase with the off-on timer, wild rats were effectively repelled. Intermittent sounds of half-octaves (6-9, 9-12, 12-16 kc) were not as effective as frequencies varied through an entire octave. In a mouse-infested warehouse, an ultrasonic (19 kc) burglar alarm proved ineffective in frightening house mice (*Mus musculus*). Only under laboratory conditions can wild rodents apparently be controlled by sounds that will cause them to die from epileptiform seizures. The necessary intensities of 130 db or above are too costly and dangerous for use in the field. One experiment utilizing rat distress calls effectively repelled the test rat. In our experiments, ultrasonics did not repel rats and mice from any of the tested areas. Data on behavioral responses of rats to sound pressures are still insufficient to answer all questions on the potential uses of sound as a deterrent to rats.

Those responsible for the storage of food items are continually fighting the ever-present rat. Reasonable control of these pests has been maintained by persistent use of poison bait stations, traps, electrical barriers, and various means of rodent-proof construction or, where feasible, by removal of cover and food supply. These methods are well covered in the literature; for example, see Chitty and Southern (1954), Bentley (1960), Scott (1961), and Johnson and Bjornson (1964). However, since many rat problems cannot be solved either by sanitation procedures or rodent-proof construction, there is prodigious use of rodenticides. The need for a nontoxic repellent is also indicated, however, since the use of poisons may be restricted, as in warehouses where food for human consumption is being stored, or where the mere entry of a rat, which conceivably might urinate or defecate on food or packages before being trapped

or poisoned, cannot be tolerated. The potential advantage of an audible, or better yet, an ultrasonic "Pied Piper" in reverse to drive rats from a premise is obvious.

There are many ways in which sound might conceivably be used either to frighten rats from a building or to discourage them from crossing a "sound barrier" to enter an area that is new to them. Even though it may be extremely difficult to develop acoustical frightening devices that will effectively eject rats from warehouses and other buildings, since rats readily habituate to new sounds, it may be easier to utilize sound pressure in a way that will discourage a rat from approaching the source of the sound if the animals have never been on the other side of the sound barrier. With this approach, conventional methods of traps and poisons would still be needed to remove the animals already in the building, but some form of acoustical sound barrier would then prevent any new individuals from entering what is a foreign habitat to them. At the moment, this approach appears to have a greater chance of success

¹ This project received partial support from the California Committee on Relations to Electricity in Agriculture.

² Present address: RFD 5, Creeksedge Road, Davis, California.

than does a sound that will actually drive established rats from a building.

A cursory review is included of several aspects of this subject, namely, biosonics, ultrasonics, biological effects of sound, and audiogenic seizures, to help point out possible fruitful areas for future studies. This introductory review is then followed by a description of the methods and results for each of our experiments.

BIOSONICS

There exists the possibility of developing a rat deterrent by using a more sophisticated type of noise, not necessarily of great intensity, such as biosonics, in the form of rat communication signals tape-recorded and played back through speakers. The various acoustic signals of animals indicate not only considerable variety in animal language but also a high degree of specificity. According to Collias (1960), these acoustic signals fall readily into ecological and functional categories related to (1) food, (2) predators, (3) sexual behavior and related fighting, (4) parent-young interrelations, and (5) aggregations and group movements.

By communication signals we refer to sounds, patterned in time and space, produced by a single individual that, upon being received by a second individual of the same species, will influence the behavior of the latter (Tembrock 1963, Frings and Frings 1964:3-4). These will include distress (desperation calls emitted by rats when restrained or caught by a predator) and alarm calls (the sounds that rats may or may not make when they are frightened by a predator or a startling stimulus). Little practical work in this area has been done on wild rats, so the true potential of this approach is still unknown. The quality of voiced sounds depends largely on the shape of the larynx, resonant cavities, etc., and

little sophisticated research in this area is available.

Tembrock (1963) cited research of Gilse et al. (1951) which demonstrated that male and female Norway rats can be distinguished by their voices and that these differences were caused by the hormone of the male as well as by a nonhormonal sexual factor. Both have an effect on the quality of the voice. Females and castrated males become hoarse after an injection of testosterone propionate, and the change in the voice is reversible.

The possibility of being able to achieve rat control by bioacoustical means is attractive because this would utilize sound of low intensity, often not as loud as ambient noises, would be quite specific for rats, and might be a sound which the animals might not easily habituate to (Frings 1964). Alarm and distress calls (communication signals) were first used to control birds by Frings and Jumber (1954). Much research has gone into the use of alarm and distress calls of birds (Frings et al. 1955, 1957, 1958, Busnel and Giban 1960, 1965, Giban 1962, Busnel 1963, Seubert 1964).

Davis (1964) demonstrated methods for detailed acoustical analysis of vocalization of animals (mostly birds) by means of the sound spectrograph. He also pointed out pitfalls and difficulties likely to be encountered and included a useful list of specialized terms and definitions used in this field. The amount of distortion in fidelity of biosonics that can be tolerated is unknown. Similarly, little information is available on the importance of temporal patterns (rhythm), harmonic qualities, and the pitch-loudness relationships.

ULTRASONICS

Since there will always be hope that some practical way may be found of utilizing

ultrasonics as a means of exploiting a rat's susceptibility to irritating sounds, we are including herein some additional remarks about ultrasonics. After 27 days of operation with equipment producing 15-16 kc at less than 100 db in two grain elevators and 17 days' operation in a third elevator, Marsh et al. (1962) found that rat movement patterns were the same as pre-installation patterns. Claims have been made that certain ultrasonic devices have driven the rats from buildings, but none of the attempts by the authors to get critical data have supported these claims. Even so, an open mind should be maintained. Similarly, no report has come to our attention of the successful scaring of birds with ultrasonic sounds (Schmitt 1957, Brown and Sugg 1961). Hearing ranges of most species do not exceed man's and often are even lower (Schwartzkopff 1955, Frings and Slocum 1958, Spurlock 1962, Frings and Cook 1964).

Ultrasonic sounds are physically the frequencies above 15 kc but, physiologically with man, nearer 20 kc (El'Piner 1964). The main differences between audible and ultrasonic sounds is that the latter have more directional transmission properties, and the fact that man cannot hear them, so they do not disturb him as long as the intensity is not too great. Just how much ultrasonic sound man and rats are exposed to in the everyday activities of urban and rural life is not known.

Dogs and cats hear at least one octave higher than man (hence the effectiveness of the ultrasonic dog whistle) and, in general, rodents hear two or more octaves higher still (Prosser and Brown 1961:307-308). Rats are known to produce ultrasonic sounds (Anderson 1954), and to employ them in echolocation (Riley and Rosenzweig 1957), but that they display a fright response to such auditory cues has not been demonstrated to our knowledge.

We obtained no pronounced fright responses in our tests. However, Frings and Frings (1964:60) stated that rats and mice "seem to have distress calls which are ultrasonic for man. . . . They respond to them by scurrying for their holes."

Vincent (1963:215) reported that "The squeals of laboratory rats, *Rattus norvegicus*, cover frequencies from 19 to 29 kc/s; their snuffling rise[s] to 80 kc/s. This species furthermore emits pure frequencies between 21.5 and 28 kc/s having no audible component. These particular sounds last from 1 to 2.5 seconds and present a rapid modulation of frequency of 2 kc/s. They are emitted when the rats are quiet and are possibly related to the animals' thoracic movements." Schleidt (1952) observed that, in general, the smaller forms of rodents of related species are more sensitive to high frequencies than are the larger animals.

BIOLOGICAL EFFECTS OF SOUND

Ultrasonic sounds, if extremely intense, can injure or even kill rodents or other organisms (Frings and Senkovits 1951). Allen et al. (1948:63) showed that white mice died after 1 minute of exposure to a sound field with a frequency of about 20 kc and an acoustic level between 160 and 165 db (relative to 10^{-16} watts/cm²). They also noted that "A mouse whose fur was removed lived about 2½ minutes longer in the sound field. . . . It would appear then that the sound on being absorbed raises the temperature sufficiently to kill the mice; that in normal mice there is much greater absorption in the fur and consequently quicker death results." According to Danner et al. (1954:738), "The threshold intensity at 18-20 kc for heating of hairless mice is as much as 10-12 db higher than for haired mice." Consequently, pest control by sonic destruction does not appear

reasonable (Frings and Frings 1960:17). Sound fields of such high intensity are not practical because they are too expensive to produce and are extremely limited in the area and distance they will cover effectively.

AUDIOGENIC SEIZURES

Audiogenic seizures may be either audible or ultrasonic sound pressures. The phenomenon of audiogenic seizures has long been regarded as a paradoxical behavioral response, which has been classified as an epileptic-like reaction in a conflict-producing situation with no escape provision (Bevan 1955). According to Frings and Frings (1952), the frequency most effective in inducing audiogenic seizures in mice is audible (10 kc), and an average intensity of about 110 db. Unlike mice, rats seldom die from audiogenic seizures. The inheritance of susceptibility to audiogenic seizures is complex, probably being multi-genic and quantitative (Frings et al. 1956: 51). Reviews of the extensive literature on seizures include Finger (1947), Busnel (1963), and Lehmann and Busnel (1963). In our tests with audiogenic seizures, no way has been found to utilize this phenomenon in the control of rats and mice.

EXPERIMENT I

Materials and Procedure

The principal technique was to provide the animal free choice of three environments. The three environments consisted of three plywood boxes or cages 6 × 6 ft with a peaked top about 5 ft higher in the center. The 6- × 6-ft boxes were placed in a triangle and were interconnected by short tunnels, allowing the rat to pass freely from any one box to either of the other two.

The sound system consisted of: (1) a Hewlett Packard Model 200 CD oscillator

which produces a pure sine wave signal; (2) a military surplus 25-watt amplifier model AM20/TIQ-2; and (3) the speakers (120-degree 12-inch diameter cone-type).

One speaker was mounted in the peaked top of each box. A switching control allowed a selection of one or more speakers to be turned on. All sound level measurements were made with a General Radio type 1551A sound level meter with a condenser microphone system type 1551-PI.

All food, water, and nesting materials were placed in the box subjected to the sound. The wild rat was allowed to get acquainted with his new environment for 2 days before the sound was turned on. A single frequency was turned on, visual observations were taken, and food consumption was noted. The frequencies used were from 100 to 16,000 cps. The sound level varied slightly around 100 db. This same test was repeated with food in all three boxes. Again, visual observations were taken and food consumption was noted. To determine the rat's activity while in one of the boxes, supplementary feeding sites were added by installing a two-story lath lattice structure in each box and designating 10 bait sites in each structure. One bait spot was only 12 inches from the speaker. In each box a single sunflower seed or a kernel of wheat was placed at each of the 10 sites to measure the extent to which this supplemental feed would be utilized.

Results

Two wild rats were used separately for a total of 67 days and were subjected to continuous and intermittent sounds varying from 100 to 19,000 cps at intensities of 60-126 db. No significant fright response was observed, except occasionally when an extraneous "cricket" sound was produced when the oscillator was switched on and

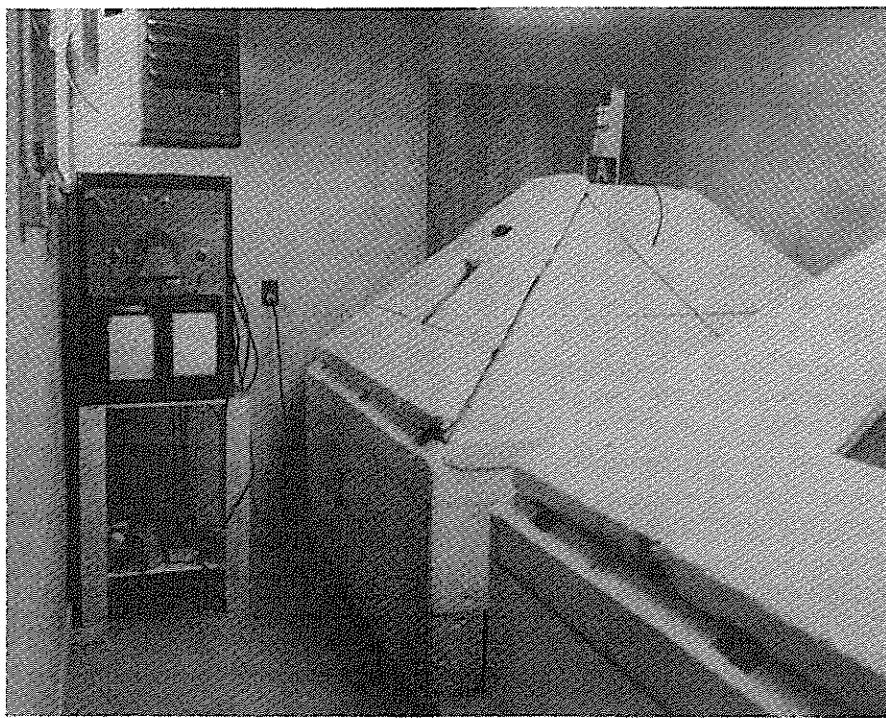


Fig. 1. Instrumentation panel and two of the three experimental sound boxes.

off. Sometimes a rat removed all of the bait spots in a box with a sound intensity as high as 126 db while a surplus of food was available in the "quiet" box.

In the acoustic chambers with 10 feeding stations on each lattice structure, both test rats visited the bait sites in the box(es) where the sounds were produced as frequently as they did the baits in the control box(es). That there was no significant difference between the number of seeds taken in the test and control boxes is borne out in the following 41-day experiment. The frequency with which the rat took the greatest number of seeds in the various boxes, depending upon the treatment, is as follows: the greatest number were taken in the control box(es) on 12 (29 percent) days, and in the box(es) where sounds were produced on 14 (34 percent) of the 41 days; and on 15 (37 percent) days the same

number of seeds were taken from the feeding spots in both the "quiet" and test chambers. Food and water were provided ad libitum in all three boxes except during the first 10 recordings, when food and water were available only in the box where the sounds were produced.

The only positive behavioral response displayed by a rat with respect to the sound pressure was that it almost always chose to "live" in a control box rather than in one where speakers were operating. Out of 51 observations, with and without feeding stations, when it could definitely be determined which box the animal was residing in at the time the chambers were examined on the following morning, on only six occasions (12 percent) was the rat found to be residing in the box where sound was being produced. On 7 of the 51 days in this test the speakers operated simultaneously in two

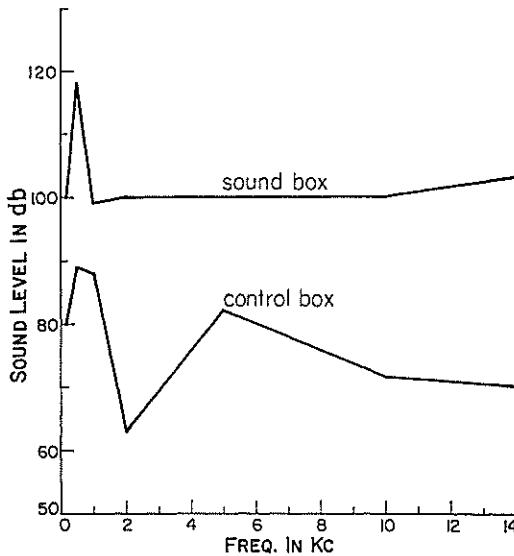


Fig. 2. Difference in sound level of energized box and control box without acoustic insulation.

acoustical chambers. In all tests the sound and control boxes were reversed periodically to avoid any fixation by the animals for a particular home box.

Continuous sound pressures of less than 120 db at any frequency from 4-16 kc proved to be ineffective in deterring wild rats under the conditions of this experiment using the three sound boxes.

EXPERIMENT II

Materials and Procedure

To enhance Experiment I, changes were made in the equipment and the system for collecting data. Each box was provided with sound proofing, first by using 2 inches of Fiberglas and later by using two inches of styrofoam (Fig. 1). There was no way of completely eliminating from "quiet" box(es) the sounds produced in the test box. The intensity differences between the quiet and energized box varied from 20 db at 100 cps to 30 db at 14,000 cps. When readings were taken in the boxes during

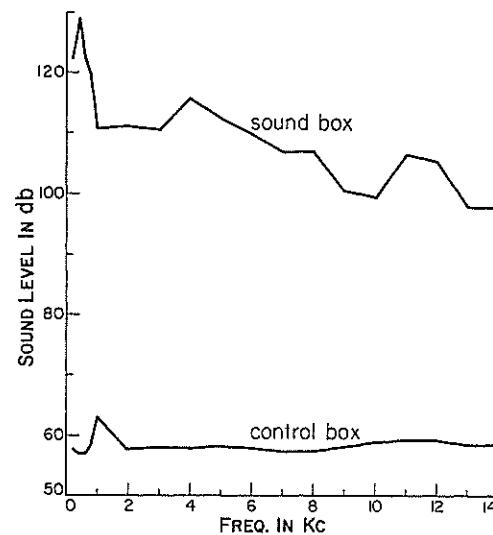


Fig. 3. Difference in sound level of energized box and control box with acoustic insulation.

experiments of 99-126 db, ranging from 100 to 14,000 cps, the difference in decibels between the sound box and the control box varied inconsistently, with an average difference of 25 db (Fig. 2). This inadequate shielding may have permitted the rats to condition rapidly to the sounds. The 2-inch-thick insulation installed on the exterior surface of the chambers improved this condition. Then with a sound level of 100 db with frequencies ranging from 500 to 10,000 cps, the intensity difference between the chamber with a speaker and the control box averaged 40 db (Fig. 3) instead of only 25 db. Since the decibel is proportional to the logarithm of a ratio, these respective differences correspond to sound pressure ratios of 100 and 17.78.

A treadle device was installed in the tunnels and connected to 24-hour clocks in an attempt to record how much time the wild rat spent in each box. This technique did not work well, because a repellent clicking sound was produced when the treadle tripped to a different electrical contact.

Rodents are startled by sounds of short duration. The treadle device was replaced with photoelectric switches but certain rats produced multiple recordings during a single passage by twitching their tail up and down in front of the photoelectric cell. To overcome this difficulty the photoelectric switches were replaced by a simple weight-operated treadle board. As the rat entered the box from the tunnel, a switch on the treadle board turned on the clock through a holding relay circuit. When the rat returned to the other box, it reset the clock system and turned on the other clock. This system necessitated changing the box arrangement so that the rat had access to either side box from the center box. The side boxes were labeled "a" and "c" and the center box labeled "b." Also the nesting material was in the center box ("b") with no food or water, and equal food and water were placed in the other two boxes ("a" and "c"). The boxes with the food and water were then alternately subjected to the sound. The frequency control of the oscillator was constantly varied through an adjustable linkage driven by a 2-rpm motor. The sound could be adjusted to cover a full or one-half octave, and the signal was fed through an interrupter control (Industrial timer CM-2), which was on for 2 out of every 10 seconds.

Results

The wild rat was introduced to the system as in Experiment I. This technique produced the first reliable and more complete data. The interrupted frequency ranges used were from 1.8-4 kc, 4-8 kc, and 8-16 kc. The experiment was operated continuously, on a 24-hour basis, for 100 days. Treatments were for a 7-day period. There was no discernable difference of time the rat spent in the box with the sound of 1.8-4 kc, a daily average of 3.15 hours,

versus the box without the sound, a daily average of 3.2 hours. A marked difference was noted with the frequency of 4-8 kc. The rat spent a daily average of 5.4 hours in the box without the sound and only 0.76 hours in the box with the sound. Again at 8-16 kc, the rat spent a daily average of 6.7 hours in the box without the sound and 1.7 hours in the box with the sound. In only one case did a rat spend more time in the box with the sound (8-16 kc) than in the box without. This was for a 6-day period with a daily average of 4.9 hours with the sound versus 1.6 hours without the sound. However, in the previous 7-day period the same rat spent a daily average of 4.5 hours in the box without the sound and 0.5 hours in the box with the sound.

The seeds removed from the lattice feeding stations averaged 50 percent in the box without the sound and 30 percent in the box with the sound (4-8 kc and 8-16 kc). The only conclusion is that the rat began foraging soon after entering a box.

EXPERIMENT III

Materials and Procedure

The basic sound boxes used were the same as in Experiments I and II. A McIntosh (MC-30) 30-watt amplifier replaced the surplus amplifier and an Ionovac speaker system was used to produce ultrasonic frequencies (16-48 kc) with a sound level of 95 db at a distance of 3 ft from the speaker. The 12-inch cone speakers would readily burn out, so they were replaced by a 50-watt driver, with a horn, (University Model T 50) in boxes "a" and "c." A sound level of 100 db or more was maintained with the 50-watt driver and horn for frequencies below 16 kc.

So that data could be gathered at a faster rate, one-way tunnels were designed to allow only one rat at a time to enter or

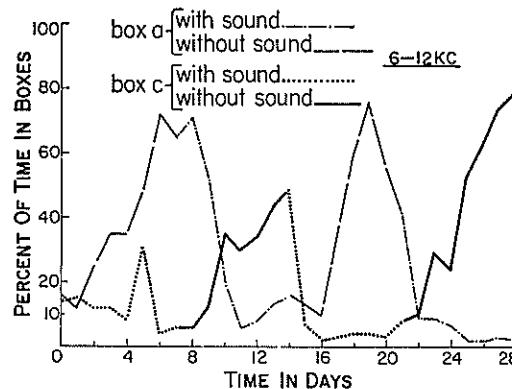


Fig. 4. Percentage of time laboratory rats spent in boxes a and c depending upon the presence of sound at 6-12 kc.

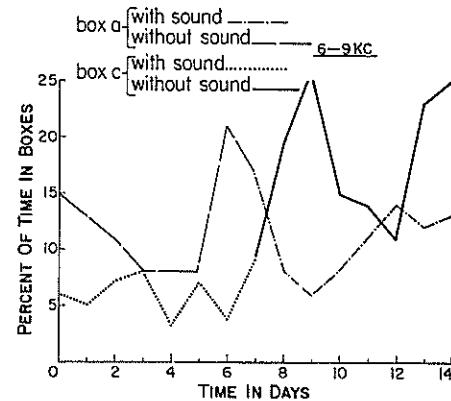


Fig. 5. Percentage of time laboratory rats spent in boxes a and c depending upon the presence of sound at 6-9 kc.

leave a box. Each visit automatically recorded the elapsed time on a chart. Ten white rats of the same sex were simultaneously introduced to the system. As a rat would pass through the one-way tunnel to one of the boxes, the pen on the recorder would advance to position one, and so on. When a rat departed the pen returned one position. This was accomplished by using add-and-subtract relays with a voltage divider arrangement so as to advance a millivolt strip-chart recorder (Esterline-Angus Model AW). Two such systems were employed for boxes "a" and "c," which were alternately subjected to the sound. This was the system which gave the most data, that is, total number of rat-hours (number of individuals \times time each spent in box) for each box.

Results

Groups of 10 white rats treated with interrupted varying pitches between 100 and 120 db intensities showed no measurable response to ranges of 2-4 kc and 4-8 kc, but were deterred by the full octave range of 6-12 kc (Fig. 4). Some deterrence occurred between 6-16 kc. When the frequency sweep was reduced to just one-half

an octave—6-9 kc (Fig. 5), 9-12 kc, or 12-16 kc—the sounds were not nearly as effective as was the entire octave of 6-12 kc.

Intermittent sweeping sounds covering an entire octave (24-48 kc) proved not to be an effective deterrent on a single rat, as was expected (Fig. 6). Similarly, these test rats were not repelled when 12-24 kc were used (Fig. 7). Treatments were for continuous 7-day periods; then the test and control boxes were reversed. The subjects often did not produce marked response to the sounds until after the treatment had been going several days.

When 10 wild rats were substituted for the white rats, social and instrumentation difficulties resulted, so this approach was abandoned.

EXPERIMENT IV

Another technique used consisted of recording the "distress" calls that a rat made when it was fed to and killed by a skunk. These sounds were then played back intermittently in the boxes in a similar manner as the above-mentioned audio-frequency tests, except that a continuous tape-player (Viking Model 35) replaced the oscillator.

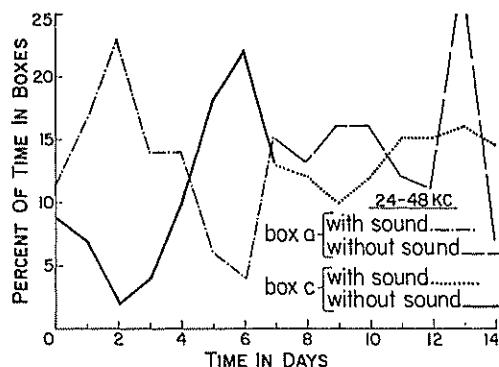


Fig. 6. Percentage of time test laboratory rats spent in boxes a and c depending upon the presence of sound at 24-48 kc.

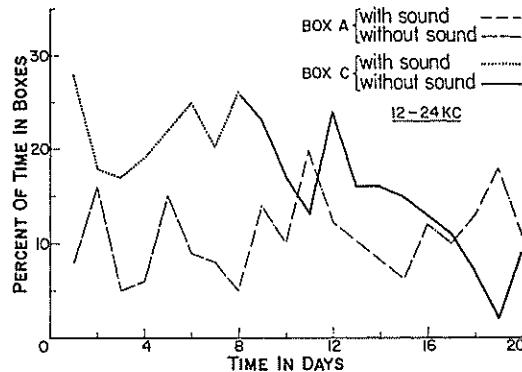


Fig. 7. Percentage of time test laboratory rats spent in boxes a and c depending upon the presence of sound at 12-24 kc.

The tape-player was programmed to play for 1 minute out of 6 using an Intermatic Timer Model C 8301-S. The wild rat spent fewer hours in the box receiving the intermittent varying-frequency distress call (Fig. 8). One wild rat developed a strong fixation for one corner of one box, and even the distress calls could not move him into a quiet box.

The distress-call technique appears to be more promising than the other systems that were studied for controlling rats.

EXPERIMENT V

An experiment was also tried in a 15- × 15-ft room. In this test, three small push-up doors of different shapes opening into a common food hopper were wired to three separate oscillators of 6, 9, and 12 kc. When a rat opened a door to feed, it automatically turned on the corresponding sound, and the length of time the animal spent feeding at that station was recorded on time clocks. This technique was expected to reveal which of the three sounds was most disturbing to the rats. However, there was no significant difference in feeding time at the three hoppers.

EXPERIMENT VI

Materials and Procedure

One acoustic device tested was a Walter Kidde and Company Master Control Unit MC-110 with speaker Sp-311, which is an ultrasonic burglar alarm. This equipment produced low-intensity energy at about 19 kc. This unit was tested in the three acoustic chambers and also in a mouse-infested warehouse, because it had been stated in *Popular Mechanics* (February 1958:135) that this device drove rodents from a building where it was installed. The seed storage warehouse used was a corrugated steel shed of 25 × 50 ft, although only about 25 × 25 ft of floor space was involved; the remainder was fairly clean.

Results

Results with the Walter Kidde ultrasonic generator, or burglar alarm, were negative in our tests with both mice and rats. The instrument operated at a frequency of about 19 kc. Three feet in front of it and on the axis of the speaker, our sound level meter indicated 90 db. Ten feet away the level had dropped to the ambient noise level of about 65 db. In a subjective test we found

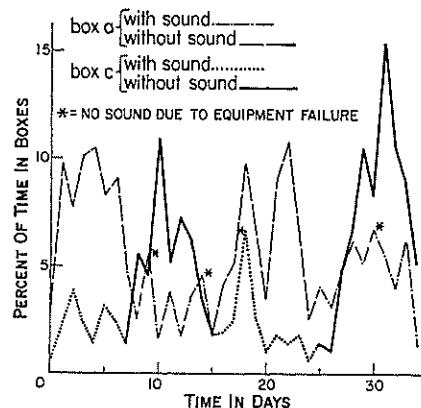


Fig. 8. Percentage of time test wild rat spent in boxes a and c depending upon the playing of a recorded rat distress call produced by a rat being fed to a skunk.

that staff members 30 years or older usually could not hear the generator from a distance of over 6 ft. Most staff and students under 25 could hear it at distances of 10–20 ft.

When this device was tested on rats in the sound boxes, no response was observed. The results were also negative with mice in the seed storage shed. The ultrasonic generator was placed 6 ft above the floor on a wall with most of the test area 10–20 ft in front. It was operated continuously for 60 days, except when briefly relocated closer to the broken sacks of seeds while an observer sat quietly nearby. The mice remained fairly numerous throughout the study and could easily be observed if one stood still for a few minutes. On one occasion a mouse voluntarily came within 12 inches of the front of the speaker, without any apparent awareness that the speaker was functioning. The mouse did not display rapid shivering of its vibrissae or make sharp movements of its ear auricle (Preyer's reflex) when it moved in front of the speaker. At the end of the 60-day test, seven mice were captured out of 10 traps set overnight. At no time during the 2 months was any exodus, fear, or abnormal activity demonstrated by the mice because

of the speaker. There was ample cover for the mice among the sacks, but they were regularly observed voluntarily emerging from this cover while the speaker was operating.

EXPERIMENT VII

Materials and Procedure

Wild rats, house mice, and inbred strains of laboratory mice (C57BL/6 Jax and DBA/1 Jax) from the Roscoe B. Jackson Memorial Laboratory, Bar Harbor, Maine, were subjected to short blasts (5–70 seconds) of sound frequencies ranging up to 25 kc and at intensities from 120–140 db to see whether audiogenic seizures or other direct detrimental physiological effects would occur.

The sound generator was a siren with a 6-inch rotor. The rotor speed was controlled by a variable speed motor which determined the frequency. The intensity was controlled by the amount of air pressure and volume applied through the rotor. The intensity was monitored by the sound level meter (previously mentioned) and the frequency was determined by feeding the output of the sound level meter into a Hewlett Packard frequency meter model 500B. The duration of the sound generated was limited to the air supply.

Results

After a number of exploratory tests were run, using frequencies ranging from audible to 25 kc at 110–140 db for periods from 5 seconds to 15 minutes, it became apparent that there was no practical way of using audiogenic seizures in the control of rodents. A few of the more interesting findings follow. No audiogenic seizures were produced in rats or mice by continuous tones of less than 100 db. The more effective frequency appeared to be about 20 kc

for mice and 8 kc for the rats, although more tests are needed to verify this. Out of nine house mice treated, only three succumbed and those only after repeated treatment. With three pairs of inbred mice (DBA/1 Jax), only the males went into fatal seizures. No seizures were obtained with the C57BL/C Jax strain.

With repeated exposures to sounds ranging up to 25 kc and above at intensities of 120–140 db, no fatal seizures were obtained with three wild rats, although one non-fatal seizure occurred. This one rat proved interesting. It would go into a nonlethal seizure when exposed to continuous sound of 8 kc at 130–140 db. But the seizure could not be repeated until the animal had been rested from this sound for several days. When the same sound pressures were produced again without the rest period, the rat apparently was unable to detect the sound. When two subadult wild rats were subjected to continuous sound of 8 kc at 130–140 db, both had seizures. Both showed signs of recovery, but one died. Fifteen minutes later, the surviving animal was re-treated and went into a prolonged seizure. A third treatment did not cause a seizure.

DISCUSSION

To determine the feasibility of using sound to produce an unlivable sound environment (for rats and mice), or even to keep them away from specific areas, is a sizable undertaking. Eight years of evaluation of basic principles inherent to the use of acoustical frightening devices produced only negative results. None of the combinations tested will effectively extirpate rodents from a storage building by stimulating their receptors (ears or some other vibratory receptor). However, this does not prove that such an acoustical device will never be discovered.

Unfortunately, there are a number of basic reasons why ultrasonic sounds may never be very successful as a rat and mouse deterrent. For one thing, they are more directional than lower and audible frequencies. They do not readily reflect around corners or transmit through solid substrates. Also they are more rapidly attenuated in the air and hence do not project as far as lower frequencies of the same intensity. As the frequency rises, the intense portion of the sound beam becomes progressively narrower and carries less distance. This means that ultrasonic sounds will not project well over any great distance or behind stored produce. Similarly, these high-frequency sounds will not readily penetrate rodent burrows and nests. It is possible, however, that high-intensity ultrasonic tweeters installed within a few feet of a small opening will to some extent deter rats and mice from passing through the opening. The effects of infrasound—that is, air vibrations which oscillate at less than 10 vibrations a second—on rats and mice were not studied.

Perhaps the most important factor to be considered for the use of either ultrasonics or audible sounds as a rodent deterrent is to have them presented to the animals in some erratic pattern. Intermittent output, plus a frequency that is varied out of phase with the off-on timer, will help to reduce or circumvent a rodent's innate ability to habituate quickly to any continuous or uniformly repeated visual or acoustical stimulus. As an example of how readily animals can accommodate to loud noises and vibrations, witness the animal life which has adjusted to the sound intensity of jet airplanes and the vibrations of trains and trucks. But, we must also remember that a great many kinds of loud noises, with or without the addition of visual devices (motion or lights), are yet to be tested. One such possible source of a reasonably effective loud noise

could be transistor radios tuned to different all-night stations and arranged to go on intermittently for brief but varying time intervals!

LITERATURE CITED

ALLEN, C. H., H. FRINGS, AND I. RUDNICK. 1948. Some biological effects of intense high frequency airborne sound. *J. Acoust. Soc. Am.* 20(1):62-65.

ANDERSON, J. W. 1954. The production of ultrasonic sounds by laboratory rats and other mammals. *Science* 119(3103):808-809.

BENTLEY, E. W. 1960. Control of rats in sewers. Ministry of Agr., Fisheries and Food, London, *Tech. Bull.* 10. 22pp.

BEVAN, W. 1955. Sound-precipitated convulsions: 1947 to 1954. *Psychol. Bull.* 52(6): 473-504.

BROWN, R. G. B., AND R. W. SUGG. 1961. Experiments on the removal of birds from airfield by distress calls. Pt. 1. Ministry of Aviation, London. Pp. 1-39.

BUSNEL, R. G. (Editor). 1963. Acoustic behaviour of animals. Elsevier Publ. Co., New York. 933pp.

_____, AND J. GIBAN (Editors). 1960. [Colloque on protecting crops by sounds and other means of frightening birds.] (In French.) *Ann. Épiphyses* 11 (No. Hors Sér.), Inst. Natl. Rech. Agron., Paris. 246pp.

_____, AND _____. (Editors). 1965. [The problem of birds at airports.] (In French.) Colloque à Nice, Nov. 1963. Inst. Natl. Rech. Agron., Paris. 326pp.

CHITTY, D., AND H. N. SOUTHERN (Editors). 1954. Control of rats and mice. 3 vols. Clarendon Press, Oxford. 757pp.

COLLIAS, N. E. 1960. An ecological and functional classification of animal sounds. Pp. 368-391. In W. E. Lanyon and W. N. Tavolga (Editors), *Animal sounds*. Am. Inst. Biol. Sci. Pub. 7. 443pp.

DANNER, P. A., E. ACKERMAN, AND H. W. FRINGS. 1954. Heating of haired and hairless mice in high intensity sound fields from 6 to 22 kc. *J. Acoust. Soc. Am.* 26(5):731-739.

DAVIS, L. I. 1964. Biological acoustics and the use of the sound spectrograph. *Southwestern Naturalist* 9(3):118-145.

EL'PINER, I. E. (Trans. by F. L. Sinclair). 1964. Ultrasound—physical, chemical, and biological effects. Consultants Bureau, New York. 371pp.

FINGER, F. W. 1947. Convulsive behavior in the rat. *Psychol. Bull.* 44(3):201-248.

FRINGS, H. 1964. Sound in vertebrate pest control. Pp. 50-56. In *Second Vert. Pest Control Conf.*, Agr. Exten. Serv., Univ. California, Davis. 160pp.

_____, AND BETTY COOK. 1964. The upper frequency limits of hearing in the European starling. *Condor* 66(1):56-60.

_____, AND MABLE FRINGS. 1952. Latent periods of audiogenic seizures in mice. *J. Mammal.* 33(4):487-491.

_____, AND _____. 1957. Recorded calls of the eastern crow as attractants and repellents. *J. Wildl. Mgmt.* 21(1):91.

_____, AND _____. 1960. Sounds of life. Stanford Research Inst. SRI J. 4:11-19.

_____, AND _____. 1964. Animal communication. Blaisdell Publ. Co., New York. 204pp.

_____, BEVERLY COX, AND LORRAINE PEISSNER. 1955. Recorded calls of herring gulls (*Larus argentatus*) as repellents and attractants. *Science* 121(3140):340-341.

_____, AND MILDRED HAMILTON. 1956. Experiments with albino mice from stocks selected for predictable susceptibilities to audiogenic seizures. *Behaviour* 9(1):44-52.

_____, J. JUMBER, R. G. BUSNEL, J. GIBAN, AND P. GRAMET. 1958. Reactions of American and French species of *Corvus* and *Larus* to recorded communication signals tested reciprocally. *Ecology* 39(1):126-131.

_____, AND J. JUMBER. 1954. Preliminary studies on the use of a specific sound to repel starlings (*Sturnus vulgaris*) from objectionable roosts. *Science* 119(3088):318-319.

_____, AND IRMA SENKOVITS. 1951. Destruction of the pinnae of white mice by high intensity air-borne sound. *J. Cell. Comp. Physiol.* 37(2):267-281.

_____, AND BETTY SLOCUM. 1958. Hearing ranges for several species of birds. *Auk* 75(1): 99-100.

GIBAN, J. (Editor). 1962. [Colloque on means of protection against birds damaging to agriculture.] (In French.) *Ann. Épiphyses* 13 (No. Hors Sér.), Inst. Natl. Rech. Agron., Paris. 262pp.

GILSE, P. H. G. VAN, R. T. DE JONCH, H. F. DE NOOY, AND M. WIJNANS. 1951. Sexual influences on the voice of rats. *Acta. Physiol. Pharmacol. Nederland* 2(2):237-241.

JOHNSON, W. H., AND B. F. BJORNSON. 1964. Rodent eradication and poisoning programs. Training Guide—Rodent Control Ser. VI. U. S. Public Health Serv., Communicable Disease Center, Atlanta, Georgia. 84pp.

LEHMANN, A., AND R. G. BUSNEL. 1963. A study of the audiogenic seizure. Pp. 244-274. In R. G. BUSNEL (Editor), *Acoustic behaviour of animals*. Elsevier Publ. Co., New York. 933pp.

MARSH, B. T., W. B. JACKSON, AND J. R. BECK.

1962. Use of ultrasonics in elevator rat control. *Grain Age* 3(11):27-31.

PROSSER, C. L., AND F. A. BROWN, JR. 1961. Comparative animal physiology. 2nd ed. W. B. Saunders Co., Philadelphia. 688pp.

RILEY, D. A., AND M. R. ROSENZWEIG. 1957. Echolocation in rats. *J. Comp. Physiol. Psychol.* 50(4):323-328.

SCHLEIDT, W. M. 1952. [Reactions of rodents to high frequency sound.] (In German.) *Naturwissenschaften* 39(3):69-70.

SCHMITT, N. 1957. [Starling flocks in valuable vineyard areas.] (In German.) *Deutsche Weinbau* 12(23):701-702.

SCHWARTZKOPFF, J. 1955. On the hearing of birds. *Auk* 72(4):340-347.

SCOTT, H. G. 1961. Rodent-borne disease control through rodent stoppage. Training Guide —Rodent Control Ser. V. U. S. Public Health Serv., Communicable Disease Center, Atlanta, Georgia. 52pp.

SEUBERT, J. L. 1964. Highlights of bird control research in England, France, Holland, and Germany. Pp. 150-159. *In* Second Vertebrate Pest Control Conf., Agr. Exten. Serv., Univ. California, Davis. 160pp.

SPURLOCK, E. M. 1962. Control of bird-strike hazard at airports. Stanford Research Inst. Proj. PU-3669. 35pp.

TEMBROCK, G. 1963. Acoustic behaviour of mammals. Pp. 751-786. *In* R. G. Busnel, (Editor), *Acoustic behaviour of animals*. Elsevier Publ. Co., New York. 933pp.

VINCENT, F. 1963. Acoustic signals for auto-information or echolocation. Pp. 183-227. *In* R. G. Busnel (Editor), *Acoustic behaviour of animals*. Elsevier Publ. Co., New York. 933pp.

Received for publication February 20, 1967.

SEXING DAY-OLD PHEASANTS BY SEX-LINKED DOWN COLOR¹

BERNARD C. WENTWORTH, Massachusetts Cooperative Wildlife Research Unit, University of Massachusetts, Amherst

E. MICHAEL POLLACK, Massachusetts Division of Fisheries and Game, Westboro

J. ROBERT SMYTH, JR., Department of Veterinary and Animal Science, University of Massachusetts, Amherst

Abstract: Pheasant propagation and management programs in different areas may emphasize one sex more than the other, so that to distinguish sex at an early age is advantageous. A method of determining the sex of day-old pheasant (*Phasianus colchicus*) chicks by utilizing the sex-linked mutation *di* and its wild-type allele, *Di^t* is described. The cross of dilute cocks with wild-type hens produced blonde female and wild-type male chicks. All wild-type male chicks developed a normal wild-type juvenile and adult plumage. The blonde female chicks developed straw-colored juvenile and adult plumage. Progeny of pure dilute \times dilute matings can also be sexed by differences in back down coloration, the males having a definite faint stripe in contrast to the even coloration of the female back down.

This paper describes a method of determining the sex of day-old pheasant chicks by a sex-linked down color. Many game farms have adopted the practice of eliminating all female chicks except those raised for brood stock. In states where "put and take" pheasant stocking is practiced and

only the cocks are legal game, efficiency of the game farm operation is increased when male chicks only are placed in the rearing pens of state, club, or private game farms. In some states, hens are reared for release as potential breeders and consequently it is desirable to rear predominantly females. Game farm elimination of the unwanted sex by distribution to another region, or by sacrifice, will release more brooding space for the desired sex, reduce the number of times the birds will need handling, and increase the uniformity of the flock.

¹ Contribution of the Massachusetts Cooperative Wildlife Research Unit (supported by the U. S. Bureau of Sport Fisheries and Wildlife, the Massachusetts Division of Fisheries and Game, the University of Massachusetts, and the Wildlife Management Institute) and the Massachusetts Agriculture Experiment Station.